



# Addressing the Water Consumption Riddle

Peggy Connot and  
Steve Young

The answer to this riddle could end up rippling across the country and the planet—from places like the Upper Klamath and Rio Grande basins to every other arid and semi-arid landscape where water consumption drives community discussion. When it comes to water, when does less actually mean more?

Dr. Gabriel Senay, a research physical scientist, and his colleagues at the U.S. Geological Survey's (USGS) Earth Resources Observation and Science

(EROS) Center are using data acquired from Landsat satellites to help divine an answer to that very question in the Upper Klamath River Basin of southern Oregon. With climate variability and drought having resulted in insufficient water for agriculture and aquatic life, including fish listed as endangered, regulators want to know if controlling water consumption from streams flowing into Upper Klamath Lake can help them better manage the basin's water resources at sustainable levels.

That's where Senay and his colleagues come in. EROS scientists use remotely sensed data scaled to Landsat 30-meter resolution and energy-balance principles to model the rates of evapotranspiration (ET) from the fields in the Upper Klamath River Basin. In a vegetated field, ET accounts for the movement of water to the air from soil and any waterbodies (evaporation), and from the movement of water within the plants and subsequent loss of water as vapor through stomata in the plant leaves (transpiration).

Plants regulate their tissue temperatures by balancing energy inputs and outputs. As water and nutrients are transported from the soil to the plant's leaves, transpiration plays a major role in regulating leaf temperature, balancing incoming energy from sunlight and outgoing energy from release of water vapor through the leaf surface.

What Senay and others understand is that through principles of ET and energy balance, a fully transpiring vegetated area can appear up to 40 degrees Fahrenheit cooler than bare areas with little ET. Using this knowledge in combination with local weather datasets for irrigated lands, Senay provides increasingly accurate and repeatable estimates of actual ET in a given landscape. ▶



**Above:** Water managers discuss the complexities of the Rio Grande Watershed and its history, as well as the need for runoff forecasts for downstream water users. The discussion took place in April 2018 near Embudo, New Mexico. Photo credit: Lindsay Hastings, USGS

**In-page:** A Klamath Tribes hydrologist makes a discharge measurement in the Sprague River between Beatty and Bly, OR. Irrigation lines extend on both sides of the river. Photo credit: Terrence Conlon, USGS Oregon Water Science Center

**Opposite:** Bathtub rings on Elephant Butte, a major reservoir on the Rio Grande. As of June 30, 2012, the reservoir was at only 12 percent of capacity. Photo credit: Zack Guido, Climate Assessment for the Southwest



**Above:** The Upper Rio Grande Basin Focus Area Study is looking at water use, availability, and change in the Upper Rio Grande Basin, covering 670 miles from its headwaters in Colorado through New Mexico and northern Mexico to Ft. Quitman, Texas. Photo credit: USGS

## Understanding ET to Help Solve the Water Consumption Riddle

Upper Klamath is important. It provides a home to endangered sucker fish. It also is the source of water for irrigation on the Bureau of Reclamation's Klamath Project. Droughts in recent years in the Upper Klamath River Basin have forced regulators to reduce or curtail irrigation withdrawals from streams. What those regulators need to know in order to wisely manage the water is how much additional water is flowing into Upper Klamath Lake because of the reduction in irrigation.

With his ET work, Senay offers a way to measure the amount of irrigated water that plants are consuming. Figuring out whether a reduction in irrigation translates into more water flowing into Upper Klamath Lake requires acquiring ET data during a year when irrigation is reduced and comparing it with a year when there is normal irrigation.

"Gabriel's work is really valuable," says Terrence Conlon, Studies Chief with the USGS Oregon Water Science Center in Portland, OR. "It's going to do a lot to move things forward as far as understanding how water management in the upper basin affects downstream flows."

Using independent Landsat satellite data from space for their ET maps, Senay and his group started working on the Upper Klamath River Basin issue in 2017 with funding from the Bureau of Reclamation. To begin with, they tapped into Landsat's rich, dense archive to produce a pair of ET maps from 2004 and 2006—representing a dry year and a wet year back when much less water regulation was occurring. Then they averaged the two to arrive at a baseline for comparing water usage in 2013, 2014, 2015, and 2016—years when more significant water management occurred.

While 2013 showed significant decreases in water consumption and irrigation along the tributaries upstream from Upper Klamath Lake, other years weren't so definitive, Senay said. That wasn't necessarily surprising, Conlon added.

In 2013, curtailment of irrigation in the upper basin was widespread, "so that was probably the clearest response to the management, and the easiest to say that there was a change" in water consumption, Conlon said. In years after 2013, however, the management of irrigation was more variable, including allowing irrigators to turn diversions back on if stream gages showed acceptable streamflow amounts would allow for it. "So, from a

scientific standpoint of trying to tease things out, now it's not kind of black and white; it's a lot of grays," Conlon said.

Certainly, there are other ways to measure water consumption in the upper basin, such as looking at streamflow in years with reduced irrigation and trying to compare it with years of normal irrigation. Tamara Wood of the USGS Oregon Water Science Center has developed a model using regression techniques that predicts streamflows during a year with normal irrigation based on snow accumulation, precipitation, and other climate variables. That streamflow model includes a way to overcome what is a common concern in all the various methods of study—finding a year with normal irrigation that had similar snowpack and precipitation to compare to a year with water management.

Senay's method of using a fixed year for comparison isn't dependent on streamflows, but rather bases consumption strictly on what is being consumed by plants on a field-to-field basis. So, while the streamflow model provides an estimate of flow into the lake from irrigation management at a point in a stream, "[Senay's model] provides an estimate of flow and can show where the changes in irrigation occur, and how much they contribute to the change in flow into Upper Klamath Lake," Conlon said. ▶

## Using Landsat to Locate Areas Susceptible to Future Flooding

The Upper Klamath isn't the only beneficiary of Senay's work. The use of Landsat's 30-meter resolution and thermal imaging capabilities to create detailed water consumption maps quickly and easily is proving crucial to resource management decisions in other parts of the country as well. The Upper Rio Grande Basin is a good example.

With water so valuable to agricultural, municipal, industrial, and recreational users throughout the Upper Rio Grande Basin, "it becomes really important to understand how much evaporates, when it evaporates, and where it evaporates, so we can better manage what's left of our surface water for our streamflow and for our groundwater," said Kyle Douglas-Mankin, a supervisory research hydrologist working for the USGS on the Upper Rio Grande Basin Focus Area Study. "Gabriel's work," Douglas-Mankin continued, "helps us do that."

Changes in climate and ongoing drought have reduced reservoir water supplies and turned groundwater into a crucial component for water availability in the Upper Rio Grande Basin. It also has meant an increased use of groundwater by agriculture, towns and cities, and for downriver delivery under the Rio Grande Compact involving Colorado, New Mexico, and Texas. With groundwater

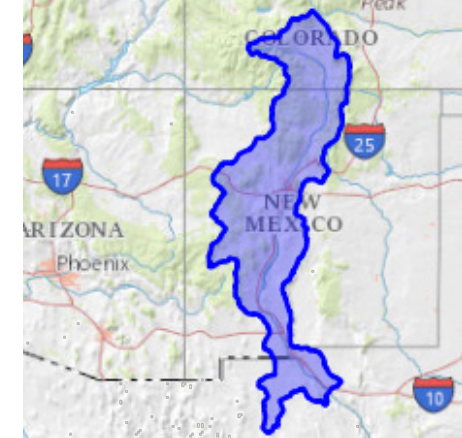
withdrawals now exceeding recharge rates in many parts of the basin, new sources of available groundwater must be identified.

## Aligning Water Use with Water Availability

Congress envisioned such a difficult challenge when it enacted the SECURE Water Act in March 2009, giving rise to a research program within the USGS called the National Water Census (NWC). Focusing on water availability and use, the NWC was implemented in February 2010 through an initiative within the Department of Interior

called WaterSMART (Sustain and Manage America's Resources for Tomorrow).

A key component of WaterSMART is the focus area studies. Among the first of the studies launched was one involving the Upper Rio Grande Basin. The Rio Grande runs 670 miles from its headwaters in Colorado through New Mexico and northern Mexico to Ft. Quitman, Texas. Along its river corridor, it is a primary source of irrigation water for food, fiber and feed production, and it also supplies municipal water to the cities of Albuquerque, Las Cruces, El Paso, and Ciudad Juarez. ▶



**Above:** The Upper Rio Grande Basin Focus Area Study includes parts of Colorado, New Mexico, Texas, and Mexico.

**In-page:** Evapotranspiration (ET), the combination of evaporation from wet soils and water bodies, as well as transpiration through plants, is the primary way water is lost from the Upper Rio Grande Basin. A study looking at consumptive water use in the basin uses satellite data to quantify where and when ET occurs. Photo credit: USGS



**Above:** The Wood River in southern Oregon is one of the large tributaries where regulators have reduced or curtailed irrigation in recent years to manage the amount of water flowing from the river into Upper Klamath Lake. Photo credit: Terrence Conlon, USGS Oregon Water Science Center

**In-page:** Evapotranspiration (ET) distribution for the San Luis Valley using Landsat data for 2018. High ET values correspond to higher water use (high irrigation). Image credit: USGS National Land Cover Database

Douglas-Mankin is working to develop a watershed model for the entire upper basin that not only captures water balance throughout the basin at a fairly fine resolution, but also looks at streamflows. He knows that some of the rain that falls will recharge the groundwater. Some will impact streamflows. But what Douglas-Mankin hopes to get from Senay and his ET modeling is a better understanding of how much of the rainfall ends up evaporating or transpiring into the air.

“How much water is left that we can use for whatever we want to use it for?” Douglas-Mankin said. “Maybe that’s drinking water, or for new agricultural development, or for maintaining streamflow for native fish. The data Gabriel provides lets us make sure we’re accounting for—what happens to the water in evapotranspiration so that we have a better chance of estimating what goes to the streams and what goes to the groundwater.”

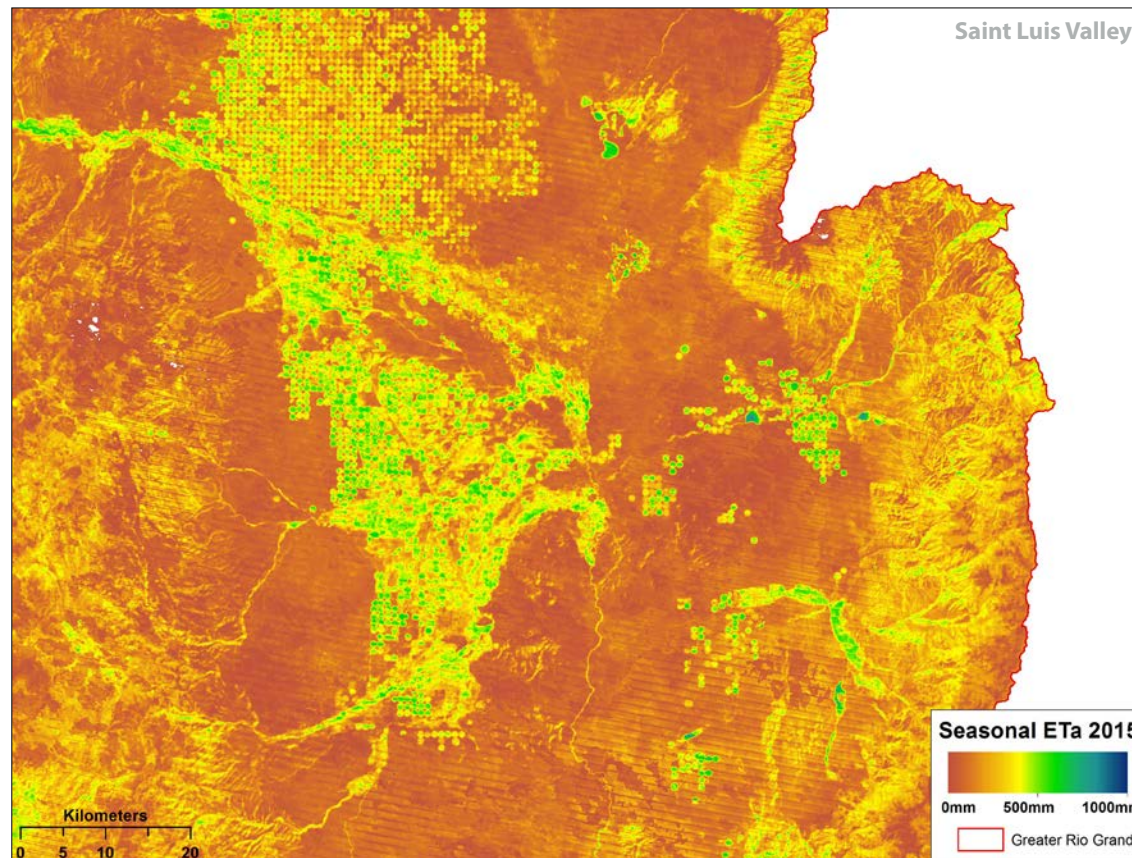
Douglas-Mankin said Senay’s monthly and seasonal ET maps at Landsat scale help to improve the measurement of water consumption on irrigated farm fields and also help to quantify water consumption through evaporation and transpiration in wetlands and other riparian ecosystems.

Senay’s ET work has an application in urban settings like Albuquerque, New Mexico, as well. In particular, using Landsat data back to 1984 can help reveal what impact urbanization has had on water consumption and climate in New Mexico’s largest city.

“When we start paving over things or we start irrigating lawns, how is that going to affect the climate of the city?” Douglas-Mankin said. “This gives us a new tool to look at that. With Gabriel’s work getting down to finer spatial and temporal resolutions, we can observe smaller lots and objects—from city blocks to backyard garden plots—with a revisit frequency of about a couple weeks.”

## ET Helps in Addressing Urban Heating

As he collects evaporation rates from the ground, Senay can tell where lawns are being irrigated, or where water isn’t evaporating from ground surfaces because they’ve been paved over. Urban heating then can be addressed by planting more trees that transpire to help cool the air and also shade homes, thus reducing air conditioning costs to homeowners and businesses. ▶



In Albuquerque, property owners are also reducing the size of their lawns to save on watering.

Another area of interest in Senay's work is east of Albuquerque, where rural developments are growing and expanding. As that happens, city and county officials need to know how much water is available to support wells and other water needs.

“One of the first things you need to understand in terms of how much groundwater is going to be able to recharge the subsurface groundwater aquifer—is how much water is lost to evaporation before it even makes it too far into the soil,” Douglas-Mankin said. “We’re using Gabriel’s data to help the county understand how much of the rainfall is evaporated and where this happens within that area.” ■

*This is a combination of two stories that ran on the EROS external website (eros.usgs.gov) under Latest Headlines. One story ran on June 27, 2018, and the other on April 26, 2018.*



The Rio Grande River making its way through Albuquerque, New Mexico. Much of the city's municipal water supply comes from the river. Researchers are using Landsat-based ET maps to access and address the impacts that urbanization has had on water consumption. Photo credit: Fotolia images

### Satellite Data Requirements:



8-day revisit (w/ L7)



≤ 30 m resolution



Vis, NIR, SWIR, TIR



Continuous spatial coverage



Archive continuity & consistency



Rapid delivery of free, unrestricted data



Geolocation ≤ 0.5 pix



≤ 5% radiance calibration



8-bit data digitization